# UPDATED GOLDEN CRAB FISHERY TRENDS AND PRODUCTION MODEL ANALYSIS BASED ON TRIP REPORT LOGBOOK AND TRIP INTERVIEW DATA COLLECTION PROGRAMS

*Report to the South Atlantic Fishery Management Council*
*Golden Crab Advisory Committee*

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## INTRODUCTION

In November 1995, a voluntary logbook program for the golden crab fishery in the waters under the jurisdiction of the South Atlantic Fishery Management Council (SAFMC) was initiated by the National Marine Fisheries Service (NMFS). This Golden Crab Trip Report Logbook program became mandatory when regulations for the golden crab fishery management plan went into effect on October 28, 1996. Regulations require that all fishers that have been issued a Federal vessel permit for the golden crab fishery in the South Atlantic region must complete and submit a logbook form for each fishing trip on which golden crabs are caught. All reporting must be done on log forms that are provided by the Southeast Fisheries Science Center (SEFSC) and must be returned to the SEFSC for data processing.

Fishing activity for a single trip is reported on one log form. The form is designed so that fishers can report the catch, number of traps, fishing location, depth and soak time for each line or string of traps that are hauled during the trip.

For regulatory purposes, the South Atlantic region is divided into 3 golden crab fishing zones. The Northern Zone is defined as the EEZ north of 28 degrees N, latitude. The Middle Zone is defined as the EEZ from 25 degrees N, latitude to 28 degrees N, latitude. The Southern Zone is defined as the EEZ south of 25 degrees N, latitude. Federal vessel permits are issued for a specific zone and fishing is only allowed in the zone for which the permit is issued.

The purpose of the logbook program was to provide a suitable method of comprehensive data collection for the fishery. Additional golden crab fishery data is available in the Trip Interview Program (TIP). TIP data collection is conducted by NMFS and state fishery agents who sample catches at the conclusion of commercial fishing trips and provides information on size

frequency of individual crabs landed. Summaries of the Golden Crab Trip Report Logbook data have been previously reported (Harper, 1996; Harper and Scott, 1998; Harper and Eyo, 1999). In addition, Harper and Scott (1998) presented a preliminary production model analysis for the golden crab fishery. This report was prepared at the request of the SAFMC and corresponds to the report identified in the FY2000 Operations Plan negotiated between the Council and NMFS. This report summarizes logbook program and TIP sampling information available through the end of March 2000 and updates the golden crab fishery production model analysis.

## Results and Discussion

The reporting regulations require that a logbook must be submitted for every trip where golden crabs are caught (possessed). If a permitted vessel did not fish during a calendar month, a report has to be submitted stating that the vessel was inactive with regard to golden crab fishing during that month. As of the end of February 1999, 546 logbook reports with catch and effort data for that trip have been submitted to the SEFSC.

Because no-fishing reports are required for a calendar month, the distribution of logbook submissions can be reviewed monthly. For the 12 month periods from November 1996 through October 1997 and November 1997 through October 1998, 25 and 18 permit holders submitted reports for every month respectively. For the period November 1998, through February 1999, 6 permit holders submitted a report for each month.

Reported Logbook Golden Crab Catches

Table 1 provides a monthly summary of the information for the 695 Golden Crab Trip Report Logbook forms which reported fishing activity. For the Middle Zone (area between 25E N, latitude and 28E N, latitude), estimated monthly golden crab catches from 538 trips completed during the entire period, November 1995 through March 2000, were 2.17 million pounds. Over the entire time period Middle Zone monthly catches averaged 41,011 pounds and ranged from 8,140 pounds for December 1998 to 84,872 pounds for May 1997 (Figure 1). Logbook report forms representing 157 trips with golden crab landings made in the Southern Zone (area south of 25º) between February 1997 and January 2000 were submitted. Southern Zone estimated golden crab catches for these reported trips were 692,327 and averaged 19,231 pounds per month over the thirty-six reported months.

Catch-per-unit-effort

The number of trap hauls reported for the 695 trips in the golden crab logbook database was 82,456 (Table 1, Figure 2). During the logbook time period the average number of traps hauled per month was 1,136 in the Middle Zone and 618 in the Southern Zone. Harper (1996) reported that golden crab catch-per-unit-effort as measured by mean catch (pounds) per trap haul was were highest during the period November 1995 through March 1996. With additional trips over a longer time period available for calculations, CPUE trends appear to be exhibiting variable seasonal patterns with peak CPUE occurring in winter-spring (December through May) and lower CPUE values calculated during summer-fall (June through November). In general, CPUE trends declined slightly in both the Middle and Southern zones between 1995 and 1998 (Figure 3). However, the 1999 CPUE data indicated an increasing trend, especially in the Middle Zone. Although variable, the Southern Zone 1999 CPUE rates were significantly higher than previously reported levels, with peak CPUE of 62.9 pounds per trap haul occurring during August 1999.

Incidental catch

Incidental catch information was estimated by fishers and reported on the Golden Crab Trip Logbook forms. The most frequently reported incidental catch species was the giant isopod, *Bathynomus giganteus*. A total of 29,547 estimated pounds of giant isopod were caught between November 1995 and March 2000 (Table 2). The overall mean catch per trap haul was 0.36 pounds and ranged from 0.09 pounds during January 1999 to 0.89 pounds during October 1998. In general, reported incidental catch of other species was very low. In addition to the giant isopod, nine other categories of species or higher taxa representing a total incidental catch of 41.6 pounds over the period November 1995 through December 1998 were reported on the logbook forms. These categories and estimated catch were: rockfish - 13.3 pounds, hake - 6.0 pounds, red crab - 6.0 pounds, queen snapper - 4.3 pounds, jonah crab - 3.8 pounds, whiting - 3.0 pounds, squid - 2.2 pounds, shrimp - 2.0 pounds, and scorpion fish - 1.0 pounds.

TIP Sampling

TIP sampling of the golden crab fishery began during May 1995. A total of 63 trips have been sampled and 10,616 golden crabs have been measured through March 2000. For the purposes of this report, all golden crabs carapace width (CW) measurements were pooled by month regardless of area fished. This pooling of data is justified based upon research indicating that there was little difference in body size and weight characteristics between Atlantic and Gulf of Mexico collected golden crab samples (Trigg et.al., 1997). Table 3 presents the monthly number of crabs measured and carapace width statistics. The overall mean carapace width of sampled golden crabs was 146.4 mm. (N=10,616, std.=12.6) and ranged from 138.1 mm (N=132,std.=12.3) during May 1998; to 157.7 mm. (N=161,std.=8.3) during January 1997 (Figure 5).

Updated Production Model Analysis

Catch and estimated effort data for the period 1986-present were refit with a non-equilibrium production model (Prager 1993) as described in Harper and Scott (1998). Golden crab quarterly catch in pounds for the South Atlantic region were obtained from the Accumulated Landings System for the period 1986 through October 1996. After 1996, golden crab catch was derived from the Golden Crab Trip Report Logbooks. Quarterly effort levels were estimated by dividing quarterly catch by observed CPUE (lbs per trap haul). CPUE data for 1986 were available in Erdman (1990). CPUE for the most recent period (1996-1999) were from the Golden Crab Logbook Reports described earlier. The production model was fit to both quarterly and annual data (annual data were compiled from the quarterly values in Table 4). However, only 5 paired annual observations of catch and effort were available, making the annual model fits more dependent upon assumptions. Results of both the quarterly and annual model fits depend upon assumptions made about the initial (1986) biomass level and for this update, we assumed that golden crab biomass was at carrying capacity at the beginning of 1986, rather than assuming the biomass was far from K. Quarterly catch and estimated effort data are provided in Table 4. For this analysis, as in Harper and Scott (1998), the first quarter of the fishing year ended in April and the last quarter ended in April of the following calendar year, resulting in a total of 56 quarters of catch (February of 1986 - January 2000) and 21 quarters of available effort information.

A total of 501 bootstrap fits of the model to the 21 paired catch and effort observations (Table 4) were used to estimate uncertainty in the model parameters of interest. As the model was fit to quarterly data, estimates of annual parameters, such as MSY or effort expected to result in MSY ($f_{MSY}$), can be obtained by multiplying the parameters of concern by 4. From this model, current biomass is estimated to be slightly below $B_{MSY}$ after having increased from lower levels in the recent past while current fishing mortality is at about $F_{MSY}$ (Figure 6). Under this model, the approximate 80% confidence range for *quarterly* MSY resulting from this fit to the fishery data is about 144,000 to 186,000 lbs per quarter with a median estimate of 171,000 lbs per quarter for the fishery as it has historically operated (Table 5). This yield would be expected from a *quarterly* effort level of about 4,800 trap hauls (~4,400 - 5,500, approximate 80% CI) within the fishing grounds the fishery has historically exploited. These quarterly estimates translate into an annual median estimate for MSY of approximately 684,000 lbs and an annual median estimate for $f_{MSY}$ of approximately 19,000 trap hauls per year within the areas and in the manner historically fished.

Fitting the model to the 5 annual catch and effort observations data results in more uncertain estimates of stock status, although the results are similar. In this case (Figure 7) current biomass is estimated to be slightly above $B_{MSY,}$ after having increased from a low in 1998 while fishing mortality is slightly below $F_{MSY}$. Under this model, the approximate 80% confidence

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range for *annual* MSY resulting from this fit to the fishery data is about 212,000 to 799,000 lbs per year with a median estimate of 673,000 lbs per year for the fishery as it has historically operated (Table 6). This yield would be expected from an annual effort level of about 22,100 trap hauls (~16,000 - 31,000, approximate 80% CI) within the fishing grounds and in the manner the fishery has historically operated. As indicated above, the quarterly estimates translated into annual estimates are more precisely determined and fall well within the confidence ranges for estimates of parameters based on annual data.

Current status and estimated uncertainty in status resulting from the production model fits relative to example limit and target control rules as outlined in Restrepo *et.al.* (1999) are shown in Figure 8 for the quarterly model fit and in Figure 9 for the annual model fit to the data.

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## MIDDLE ZONE

| Year | Month | Catch Weight (lbs) | Traps Hauled | Strings Hauled | Number Trips | Depth fished average (feet) | Soak Time average (days) |
|---|---|---|---|---|---|---|---|
| 1995 | November | 13,800 | 399 | 12 | 4 | 1,083 | 8.6 |
| | December | 48,060 | 1,202 | 34 | 13 | 1,094 | 7.6 |
| 1996 | January | 38,050 | 721 | 21 | 8 | 1,100 | 8.0 |
| | February | 32,200 | 542 | 18 | 9 | 1,100 | 8.2 |
| | March | 43,050 | 807 | 29 | 11 | 1,100 | 7.6 |
| | April | 47,950 | 1,128 | 32 | 11 | 1,097 | 17.8 |
| | May | 53,140 | 1,428 | 41 | 14 | 1,110 | 10.3 |
| | June | 49,750 | 1,931 | 50 | 12 | 1,131 | 7.4 |
| | July | 41,705 | 1,388 | 39 | 11 | 1,162 | 7.3 |
| | August | 46,950 | 1,525 | 41 | 13 | 1,184 | 11.1 |
| | September | 49,000 | 1,595 | 44 | 13 | 1,202 | 6.5 |
| | October | 32,835 | 1,079 | 33 | 10 | 1,223 | 17.9 |
| | November | 28,800 | 980 | 27 | 9 | 1,215 | 9.3 |
| | December | 62,850 | 1,608 | 44 | 13 | 1,188 | 8.0 |
| 1997 | January | 72,020 | 1,580 | 45 | 13 | 1,178 | 8.2 |
| | February | 57,100 | 1,202 | 35 | 10 | 1,156 | 10.5 |
| | March | 58,920 | 1,288 | 34 | 12 | 1,089 | 6.9 |
| | April | 52,900 | 1,417 | 37 | 12 | 1,104 | 10.5 |
| | May | 84,872 | 2,008 | 58 | 17 | 1,201 | 8.5 |
| | June | 43,580 | 1,098 | 30 | 10 | 1,103 | 7.9 |
| | July | 60,548 | 1,652 | 48 | 18 | 1,145 | 10.4 |
| | August | 63,035 | 1,790 | 47 | 15 | 1,191 | 8.5 |
| | September | 65,230 | 1,484 | 39 | 12 | 1,191 | 8.8 |
| | October | 49,041 | 1,439 | 38 | 13 | 1,169 | 12.1 |
| | November | 24,500 | 788 | 21 | 8 | 1,203 | 11.0 |
| | December | 29,950 | 874 | 26 | 9 | 1,199 | 7.7 |
| 1998 | January | 35,130 | 937 | 27 | 8 | 1,194 | 10.7 |
| | February | 45,070 | 1,182 | 32 | 10 | 1,184 | 8.0 |
| | March | 43,550 | 1,134 | 29 | 10 | 1,208 | 12.6 |
| | April | 50,470 | 1,204 | 33 | 10 | 1,203 | 12.5 |
| | May | 22,785 | 830 | 28 | 12 | 1,135 | 7.9 |
| | June | 42,604 | 1,522 | 42 | 14 | 1,198 | 11.6 |
| | July | 34,790 | 1,384 | 36 | 10 | 1,202 | 9.8 |
| | August | 24,300 | 1,104 | 30 | 9 | 1,211 | 8.4 |
| | September | 10,040 | 785 | 22 | 8 | 1,218 | 9.1 |
| | October | 14,450 | 909 | 28 | 9 | 1,200 | 7.8 |
| | November | 15,407 | 857 | 24 | 8 | 1,255 | 12.3 |
| | December | 8,140 | 485 | 12 | 4 | 1,272 | 17.4 |
| 1999 | January | 10,800 | 348 | 8 | 2 | 1,234 | 16.3 |
| | February | 48,340 | 1,184 | 33 | 12 | 1,236 | 23.6 |
| | March | 47,516 | 1,328 | 33 | 12 | 1,319 | 12.4 |
| | April | 50,535 | 1,588 | 33 | 13 | 1,419 | 12.1 |
| | May | 34,623 | 983 | 26 | 9 | 1,231 | 15.8 |
| | June | 38,140 | 1,047 | 24 | 7 | 1,284 | 10.8 |
| | July | 40,934 | 943 | 25 | 10 | 1,305 | 7.7 |
| | August | 31,100 | 770 | 22 | 8 | 1,197 | 8.0 |
| | September | 22,400 | 700 | 20 | 7 | 1,191 | 8.4 |
| | October | 28,100 | 820 | 20 | 8 | 1,305 | 14.8 |
| | November | 44,100 | 1,030 | 26 | 9 | 1,312 | 12.7 |
| | December | 49,275 | 1,205 | 31 | 10 | 1,204 | 6.2 |
| 2000 | January | 52,050 | 1,035 | 27 | 8 | 1,202 | 9.7 |
| | February | 62,625 | 1,498 | 38 | 11 | 1,251 | 10.3 |
| | March | 23,825 | 575 | 16 | 5 | 1,195 | 9.9 |
| | Overall | 2,173,597 | 60,222 | 1,631 | 636 | 1,168 | 9.7 |

## SOUTHERN ZONE

| Year | Month | Catch Weight (lbs) | Traps Hauled | Strings Hauled | Number Trips | Depth fished average (feet) | Soak Time average (days) |
|---|---|---|---|---|---|---|---|
| 1997 | February | 5,212 | 155 | 3 | 2 | 1,300 | 3.0 |
| | March | 15,636 | 610 | 12 | 4 | 1,217 | 4.8 |
| | April | 24,080 | 900 | 16 | 10 | 1,358 | 8.5 |
| | May | 108,388 | 3,427 | 77 | 28 | 1,762 | 7.3 |
| | June | 67,542 | 1,692 | 39 | 17 | 1,913 | 10.4 |
| | July | 52,990 | 1,195 | 25 | 9 | 1,940 | 11.8 |
| | August | 15,760 | 397 | 8 | 4 | 1,738 | 11.6 |
| | September | 21,240 | 808 | 15 | 7 | 2,001 | 17.1 |
| | October | 15,927 | 450 | 9 | 3 | 1,933 | 20.0 |
| | November | 32,501 | 1,161 | 28 | 10 | 1,668 | 15.6 |
| | December | 10,705 | 325 | 8 | 4 | 1,600 | 17.6 |
| 1998 | January | 16,400 | 524 | 10 | 4 | 1,796 | 26.4 |
| | February | 33,307 | 1,234 | 38 | 12 | 1,370 | 15.7 |
| | March | 14,605 | 551 | 15 | 5 | 1,691 | 22.2 |
| | April | 10,505 | 630 | 18 | 3 | 1,805 | 27.9 |
| | May | | | | | | |
| | June | 4,500 | 117 | 4 | 2 | 1,075 | 10.0 |
| | July | 12,771 | 504 | 10 | 5 | 1,624 | 18.6 |
| | August | 21,650 | 1,184 | 13 | 4 | 1,933 | 9.2 |
| | September | 10,375 | 428 | 6 | 3 | 1,746 | 24.2 |
| | October | 18,600 | 931 | 10 | 8 | 1,943 | 13.1 |
| | November | 6,993 | 377 | 5 | 2 | 2,030 | 22.2 |
| | December | | | | | | |
| 1999 | January | | | | | | |
| | February | | | | | | |
| | March | | | | | | |
| | April | | | | | | |
| | May | | | | | | |
| | June | 22,720 | 876 | 11 | 8 | 1,898 | 70.4 |
| | July | 46,536 | 1,012 | 12 | 3 | 1,898 | 29.3 |
| | August | 55,955 | 888 | 10 | 3 | 1,930 | 18.0 |
| | September | 20,133 | 779 | 7 | 3 | 1,869 | 56.7 |
| | October | 16 | 528 | 1 | 1 | 2,800 | 7.0 |
| | November | | | | | | |
| | December | 13,800 | 260 | 6 | 1 | 280 | 7.0 |
| 2000 | January | 3,778 | 535 | 4 | 3 | 1,438 | 12.0 |
| | February | | | | | | |
| | March | | | | | | |
| | Overall | 692,327 | 23,234 | 426 | 157 | 1,750 | 13.5 |

**Table 1.** Monthly summary of information reported in the South Atlantic Golden Crab Trip Report Logbook (November 1995 through March 2000).

| Year | Month | Catch POUNDS | Catch per trap haul POUNDS | Catch per year POUNDS |
|------|-------|------|------|------|
| 1995 | November | 206 | 0.52 | |
| | December | 405 | 0.34 | 611 |
| 1996 | January | 190 | 0.26 | |
| | February | 105 | 0.19 | |
| | March | 291 | 0.36 | |
| | April | 168 | 0.17 | |
| | May | 171 | 0.12 | |
| | June | 607 | 0.33 | |
| | July | 646 | 0.47 | |
| | August | 499 | 0.33 | |
| | September | 813 | 0.51 | |
| | October | 659 | 0.61 | |
| | November | 476 | 0.27 | |
| | December | 607 | 0.38 | 5,252 |
| 1997 | January | 530 | 0.34 | |
| | February | 447 | 0.33 | |
| | March | 612 | 0.32 | |
| | April | 941 | 0.41 | |
| | May | 2,289 | 0.42 | |
| | June | 955 | 0.38 | |
| | July | 691 | 0.24 | |
| | August | 641 | 0.30 | |
| | September | 831 | 0.36 | |
| | October | 780 | 0.41 | |
| | November | 540 | 0.28 | |
| | December | 615 | 0.55 | 9,852 |
| 1998 | January | 547 | 0.35 | |
| | February | 539 | 0.22 | |
| | March | 436 | 0.25 | |
| | April | 218 | 0.48 | |
| | May | 465 | 0.60 | |
| | June | 724 | 0.49 | |
| | July | 886 | 0.52 | |
| | August | 1,374 | 0.57 | |
| | September | 465 | 0.42 | |
| | October | 1,475 | 0.89 | |
| | November | 750 | 0.61 | |
| | December | 275 | 0.72 | 8,054 |
| 1999 | January | 35 | 0.09 | |
| | February | 144 | 0.12 | |
| | March | 340 | 0.26 | |
| | April | 414 | 0.26 | |
| | May | 231 | 0.23 | |
| | June | 540 | 0.31 | |
| | July | 567 | 0.29 | |
| | August | 653 | 0.39 | |
| | September | 630 | 0.43 | |
| | October | 273 | 0.24 | |
| | November | 218 | 0.21 | |
| | December | 495 | 0.34 | 4,540 |
| 2000 | January | 420 | 0.27 | |
| | February | 650 | 0.43 | |
| | March | 168 | 0.29 | |
| | *Total* | 29,547 | 0.36 | |

**Table 2.** Estimated incidental giant isopod catches reported in the Golden Crab Trip Report Logbook, November 1995 through March 2000.

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**Table 3.** Monthly summary of Trip Interview Program sampling for the golden crab fishery. Individual golden crabs from commercial landings are measured to the nearest mm. carapace width (CW) by NMFS and state port agents.

| Year | Month | Number Measured | Mean CW(mm) | Standard Deviation | Minimum CW (mm) | Maximum CW (mm) |
|---|---|---|---|---|---|---|
| 1995 | May | 74 | 150.5 | 10.7 | 122 | 177 |
| | June | 353 | 146.6 | 11.1 | 119 | 175 |
| | July | 211 | 147.8 | 13.0 | 102 | 180 |
| | August | 37 | 154.7 | 20.3 | 110 | 181 |
| | September | 475 | 142.5 | 16.3 | 106 | 189 |
| | October | 108 | 154.8 | 15.2 | 111 | 186 |
| | November | 202 | 155.0 | 14.6 | 105 | 188 |
| | December | 0 | | | | |
| 1996 | January | 0 | | | | |
| | February | 229 | 146.3 | 9.7 | 118 | 169 |
| | March | 25 | 151.0 | 11.2 | 126 | 180 |
| | April | 763 | 143.5 | 10.2 | 112 | 174 |
| | May | 357 | 144.2 | 11.2 | 104 | 170 |
| | June | 206 | 142.7 | 11.1 | 111 | 170 |
| | July | 170 | 150.4 | 11.3 | 125 | 171 |
| | August | 0 | | | | |
| | September | 275 | 154.3 | 8.0 | 125 | 179 |
| | October | 138 | 156.1 | 11.1 | 124 | 180 |
| | November | 0 | | | | |
| | December | 0 | | | | |
| 1997 | January | 161 | 157.7 | 8.3 | 135 | 180 |
| | February | 0 | | | | |
| | March | 293 | 155.2 | 9.6 | 123 | 182 |
| | April | 99 | 146.4 | 10.1 | 112 | 172 |
| | May | 242 | 151.9 | 9.2 | 122 | 174 |
| | June | 223 | 151.4 | 10.0 | 123 | 183 |
| | July | 0 | | | | |
| | August | 46 | 152.7 | 8.3 | 130 | 170 |
| | September | 0 | | | | |
| | October | 0 | | | | |
| | November | 112 | 151.7 | 9.4 | 130 | 174 |
| | December | 0 | | | | |
| 1998 | January | 0 | | | | |
| | February | 0 | | | | |
| | March | 0 | | | | |
| | April | 0 | | | | |
| | May | 132 | 138.1 | 12.3 | 113 | 172 |
| | June | 0 | | | | |
| | July | 99 | 149.1 | 12.5 | 123 | 179 |
| | August | 315 | 148.0 | 10.5 | 120 | 185 |
| | September | 0 | | | | |
| | October | 70 | 152.0 | 12.1 | 123 | 175 |
| | November | 124 | 146.9 | 13.0 | 121 | 178 |
| | December | 54 | 149.6 | 13.0 | 117 | 180 |
| 1999 | January | 0 | | | | |
| | February | 254 | 141.7 | 11.9 | 114 | 175 |
| | March | 479 | 140.2 | 11.4 | 112 | 180 |
| | April | 375 | 138.5 | 11.6 | 116 | 180 |
| | May | 301 | 137.7 | 11.7 | 112 | 172 |
| | June | 867 | 143.0 | 11.6 | 115 | 188 |
| | July | 650 | 145.4 | 11.1 | 155 | 180 |
| | August | 412 | 145.6 | 12.6 | 120 | 186 |
| | September | 380 | 146.6 | 12.4 | 120 | 189 |
| | October | 247 | 150.0 | 12.6 | 125 | 186 |
| | November | 470 | 147.7 | 11.8 | 115 | 186 |
| | December | 135 | 144.6 | 11.9 | 122 | 180 |
| 2000 | January | 103 | 145.2 | 12.0 | 121 | 190 |
| | February | 273 | 154.0 | 9.6 | 125 | 181 |
| | March | 75 | 136.1 | 11.4 | 112 | 165 |
| | Total | 10,616 | 146.4 | 12.6 | 102 | 190 |

**Table 4.** Catch and effort data used in updated golden crab production models (negative values imply missing information).

| Quarter | Month Range | Trap Hauls | Pounds |
|---|---|---|---|
| 1 | Feb - Apr 1986 | 23.02 | 2,029 |
| 2 | May - Jul 1986 | 68.79 | 6,471 |
| 3 | Aug - Oct 1986 | 49.52 | 4,137 |
| 4 | Nov 1986 - Jan 1987 | 244.48 | 12,921 |
| 5 | Feb - Apr 1987 | -9 | 17,212 |
| 6 | May - Jul 1987 | -9 | 29,098 |
| 7 | Aug - Oct 1987 | -9 | 6,589 |
| 8 | Nov 1987 - Jan 1988 | -9 | 1,766 |
| 9 | Feb - Apr 1988 | -9 | 11,490 |
| 10 | May - Jul 1988 | -9 | 8,712 |
| 11 | Aug - Oct 1988 | -9 | 425 |
| 12 | Nov 1988 - Jan 1989 | -9 | 1,022 |
| 13 | Feb - Apr 1989 | -9 | 3,126 |
| 14 | May - Jul 1989 | -9 | 5,900 |
| 15 | Aug - Oct 1989 | -9 | 0 |
| 16 | Nov 1989 - Jan 1990 | -9 | 0 |
| 17 | Feb - Apr 1990 | -9 | 0 |
| 18 | May - Jul 1990 | -9 | 0 |
| 19 | Aug - Oct 1990 | -9 | 110 |
| 20 | Nov 1990 - Jan 1991 | -9 | 0 |
| 21 | Feb - Apr 1991 | -9 | 2,886 |
| 22 | May - Jul 1991 | -9 | 3,645 |
| 23 | Aug - Oct 1991 | -9 | 2,707 |
| 24 | Nov 1991 - Jan 1992 | -9 | 2,500 |
| 25 | Feb - Apr 1992 | -9 | 730 |
| 26 | May - Jul 1992 | -9 | 193 |
| 27 | Aug - Oct 1992 | -9 | 0 |
| 28 | Nov 1992 - Jan 1993 | -9 | 0 |
| 29 | Feb - Apr 1993 | -9 | 24,560 |
| 30 | May - Jul 1993 | -9 | 18,553 |
| 31 | Aug - Oct 1993 | -9 | 200 |
| 32 | Nov 1993 - Jan 1994 | -9 | 2,398 |
| 33 | Feb - Apr 1994 | -9 | 0 |
| 34 | May - Jul 1994 | -9 | 0 |
| 35 | Aug - Oct 1994 | -9 | 0 |
| 36 | Nov 1994 - Jan 1995 | -9 | 4,296 |
| 37 | Feb - Apr 1995 | -9 | 88,149 |
| 38 | May - Jul 1995 | -9 | 545,649 |
| 39 | Aug - Oct 1995 | -9 | 206,987 |
| 40 | Nov 1995 - Jan 1996 | 4,941.31 | 193,630 |
| 41 | Feb - Apr 1996 | 3,616.20 | 170,318 |
| 42 | May - Jul 1996 | 10,882.36 | 327,869 |
| 43 | Aug - Oct 1996 | 3,897.37 | 119,165 |
| 44 | Nov 1996 - Jan 1997 | 4,148 | 161,650 |
| 45 | Feb - Apr 1997 | 5,572 | 226,278 |
| 46 | May - Jul 1997 | 11,035 | 405,251 |
| 47 | Aug - Oct 1997 | 6,340 | 220,333 |
| 48 | Nov 1997 - Jan 1998 | 4,707 | 152,356 |
| 49 | Feb - Apr 1998 | 6,085 | 202,737 |
| 50 | May - Jul 1998 | 4,357 | 117,450 |
| 51 | Aug - Oct 1998 | 5,342 | 105,915 |
| 52 | Nov 1998 - Jan 1999 | 2,085 | 41,140 |
| 53 | Feb - Apr 1999 | 4,098 | 144,493 |
| 54 | May - Jul 1999 | 4,663 | 183,255 |
| 55 | Aug - Oct 1999 | 4,278 | 157,704 |
| 56 | Nov 1999 - Jan 2000 | 4,065 | 162,703 |

**Table 5**. Results of the bootstrapped analysis for the production model fit to quarterly catch and effort data under the assumption that 1986 biomass was at model carrying capacity.

| Param name | Bias-corrected estimate | Ordinary estimate | Relative bias | Approx 80% lower CL | Approx 80% upper CL | Approx 50% lower CL | Approx 50% upper CL |
|---|---|---|---|---|---|---|---|
| B1ratio | 2.000E+00 | 2.000E+00 | 0.00% | 2.000E+00 | 2.000E+00 | 2.000E+00 | 2.000E+00 |
| K | 1.675E+06 | 1.666E+06 | -0.51% | 1.284E+06 | 2.361E+06 | 1.459E+06 | 1.960E+06 |
| r | 4.110E-01 | 4.146E-01 | 0.86% | 2.554E-01 | 5.854E-01 | 3.345E-01 | 4.981E-01 |
| q(1) | 4.262E-05 | 4.331E-05 | 1.62% | 2.775E-05 | 5.707E-05 | 3.423E-05 | 4.947E-05 |
| MSY | 1.710E+05 | 1.727E+05 | 1.02% | 1.442E+05 | 1.860E+05 | 1.600E+05 | 1.791E+05 |
| Bmsy | 8.374E+05 | 8.332E+05 | -0.51% | 6.418E+05 | 1.180E+06 | 7.294E+05 | 9.798E+05 |
| Fmsy | 2.055E-01 | 2.073E-01 | 0.86% | 1.277E-01 | 2.927E-01 | 1.672E-01 | 2.490E-01 |
| fmsy(1) | 4.791E+03 | 4.787E+03 | -0.09% | 4.169E+03 | 5.524E+03 | 4.453E+03 | 5.130E+03 |
| B-ratio | 9.770E-01 | 9.924E-01 | 1.57% | 7.826E-01 | 1.167E+00 | 8.613E-01 | 1.078E+00 |
| F-ratio | 9.814E-01 | 9.549E-01 | -2.71% | 7.590E-01 | 1.381E+00 | 8.517E-01 | 1.153E+00 |

notes: B1ratio, Initial biomass expressed relative to Bmsy = K/2. A value of 2.0 implies initial biomass to be at model carrying capacity, K, r, model intrinsic rate of increase. q(1), catchability coefficient for fishery (1). MSY estimate of quarterly maximum sustainable yield. B-ratio, estimate of end of lsast quarter biomass, expressed relative to Bmsy. F-ratio, estimate of last quarter fishing mortality rate relative to that which could produce MSY. fmsy(1) estimate of the effort units needed to produce MSY for fishery (1).

**Table 6.** Results of the bootstrapped analysis for the production model fit to annual catch and effort data under the assumption that 1986 biomass was at model carrying capacity.

| Param name | Bias-corrected estimate | Ordinary estimate | Relative bias | Approx 80% lower CL | Approx 80% upper CL | Approx 50% lower CL | Approx 50% upper CL |
|---|---|---|---|---|---|---|---|
| B1ratio | 2.000E+00 | 2.000E+00 | 0.00% | 2.000E+00 | 2.000E+00 | 2.000E+00 | 2.000E+00 |
| K | 1.829E+06 | 1.696E+06 | -7.27% | 9.563E+05 | 5.003E+06 | 1.219E+06 | 3.121E+06 |
| r | 1.409E+00 | 1.651E+00 | 17.15% | 2.406E-01 | 3.277E+00 | 7.412E-01 | 2.455E+00 |
| q(1) | 3.302E-05 | 3.780E-05 | 14.46% | 9.497E-06 | 7.346E-05 | 1.637E-05 | 5.409E-05 |
| MSY | 6.728E+05 | 7.000E+05 | 4.05% | 2.122E+05 | 7.990E+05 | 5.508E+05 | 7.548E+05 |
| Ye(2000) | 7.127E+05 | 6.893E+05 | -3.28% | 6.432E+05 | 7.712E+05 | 6.804E+05 | 7.485E+05 |
| Bmsy | 9.143E+05 | 8.479E+05 | -7.27% | 4.781E+05 | 2.501E+06 | 6.096E+05 | 1.560E+06 |
| Fmsy | 7.047E-01 | 8.256E-01 | 17.15% | 1.203E-01 | 1.639E+00 | 3.706E-01 | 1.227E+00 |
| fmsy(1) | 2.209E+04 | 2.184E+04 | -1.12% | 1.559E+04 | 3.139E+04 | 1.841E+04 | 2.582E+04 |
| B-ratio | 1.103E+00 | 1.124E+00 | 1.84% | 8.010E-01 | 1.438E+00 | 9.148E-01 | 1.303E+00 |
| F-ratio | 8.490E-01 | 8.409E-01 | -0.95% | 5.237E-01 | 1.515E+00 | 6.530E-01 | 1.134E+00 |

notes: B1ratio, Initial biomass expressed relative to Bmsy = K/2. A value of 2.0 implies initial biomass to be at model carrying capacity, K, r, model intrinsic rate of increase. q(1), catchability coefficient for fishery (1). MSY estimate of annual maximum sustainable yield. B-ratio, estimate of end of last year biomass, expressed relative to Bmsy. F-ratio, estimate of last year fishing mortality rate relative to that which could produce MSY. fmsy(1) estimate of the effort units needed to produce MSY for fishery (1).
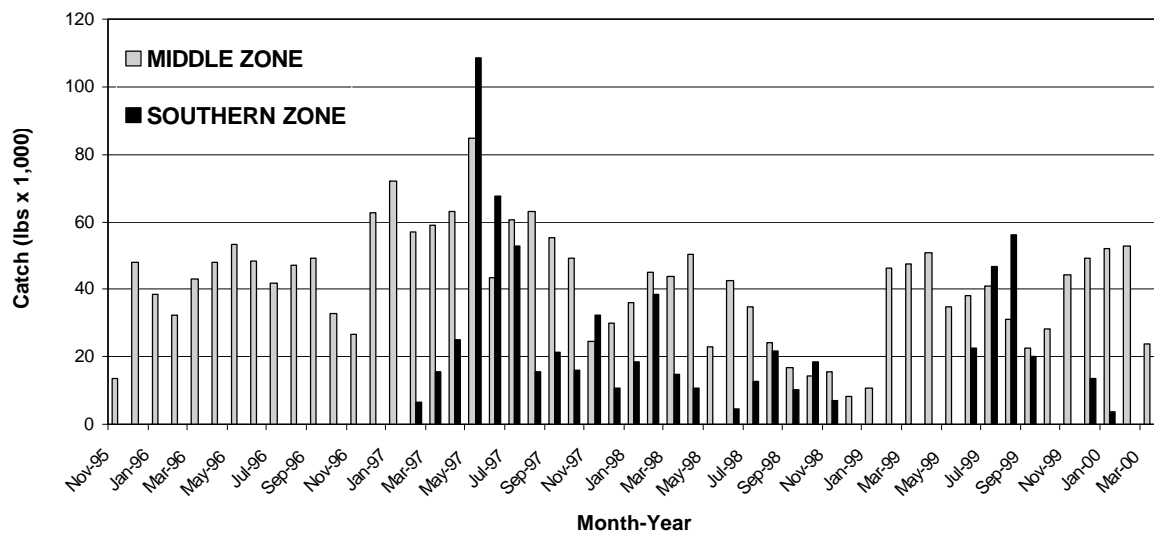
**Figure 1.** Reported catch by month and fishing zone from Golden Crab Trip Report Logbook data. A total of 695 trip forms reporting golden crab landings were submitted November 1995 through March 2000.
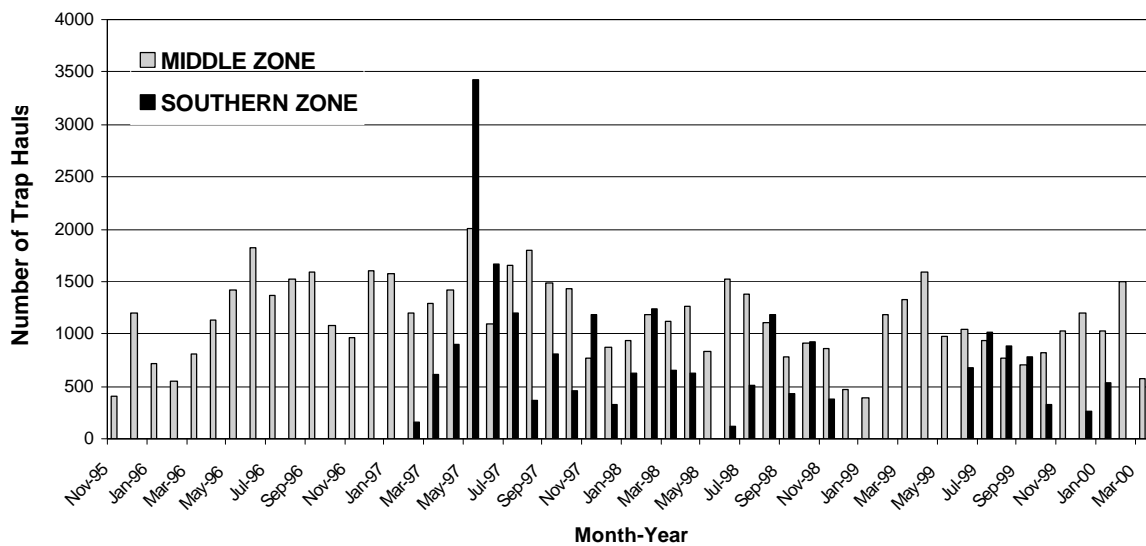


**Figure 2.** Reported number of traps hauled by month and fishing zone from the Golden Crab Trip Report Logbook data. A total of 695 logbook trip forms reporting golden crab landings were submitted November 1995 through March 2000.

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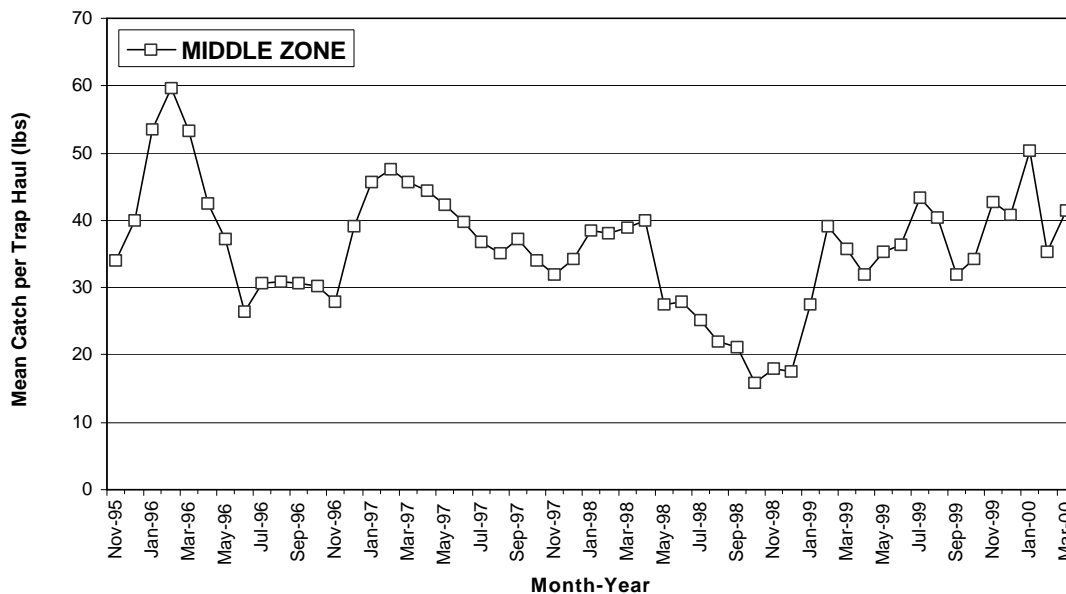
**Figure 3.** Monthly CPUE (pounds per trap haul) reported for 538 middle zone trips with landings in the Golden Crab Trip Report Logbook, November 1995 through March 2000.
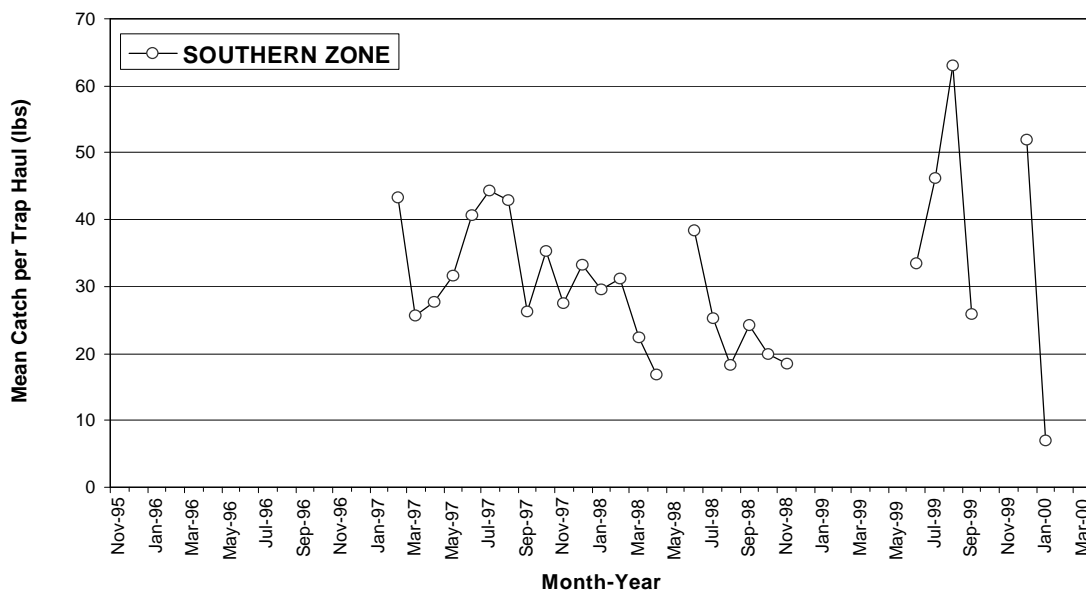


**Fig**

**ure 4.** Monthly CPUE (pounds per trap haul) reported from 157 southern zone trips with
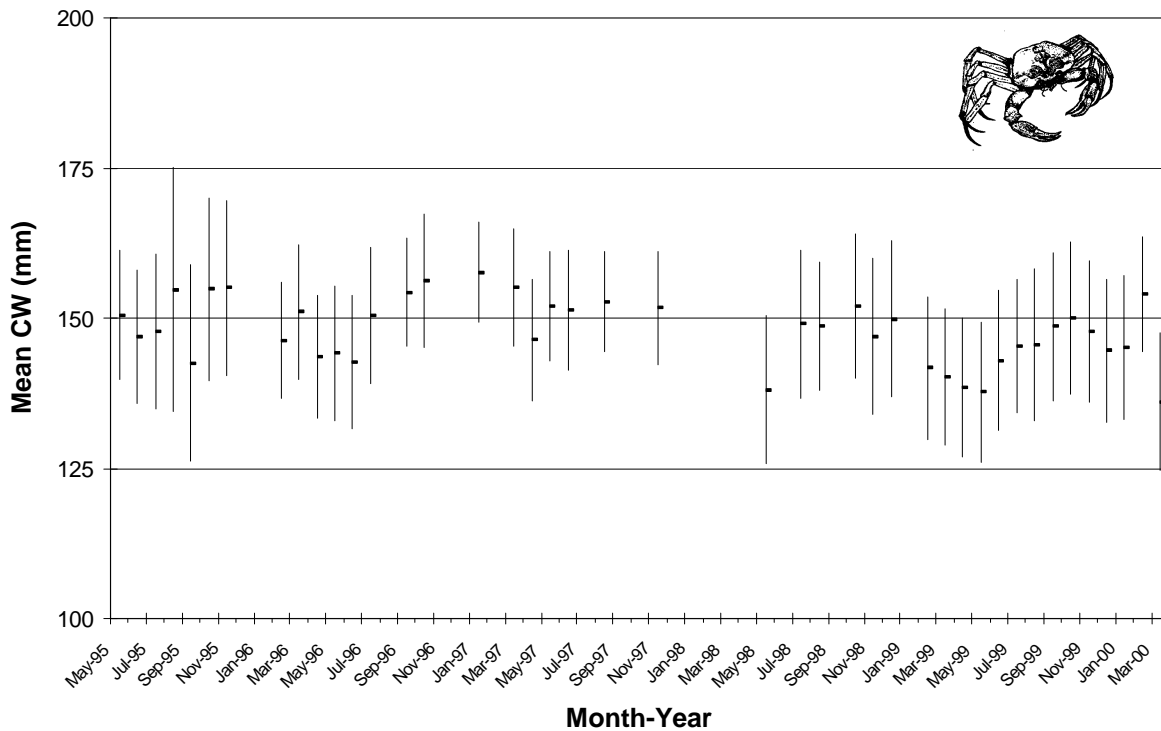
landings in the Golden Crab Trip Report Logbook February 1997 through January 2000.

**Figure 5.** Mean Monthly Carapace Width (CW im millimeters) for golden crabs sampled from commercial catches, May 1995 through March 2000. Vertical lines indicate plus or minus one standard deviation from the mean.
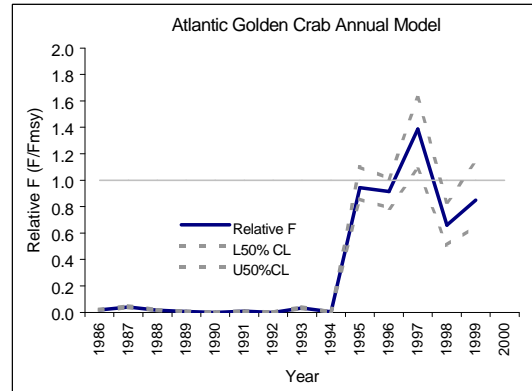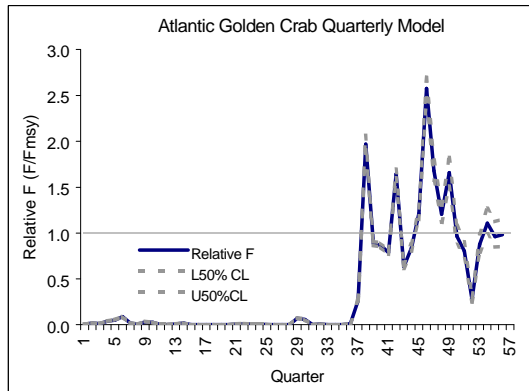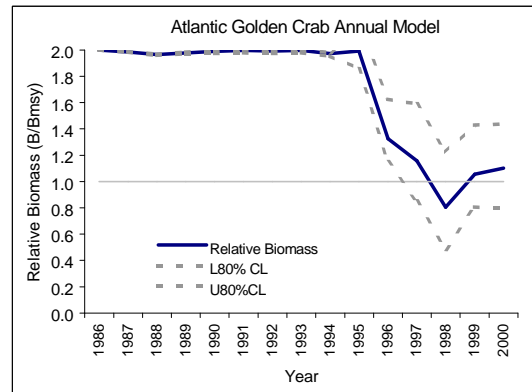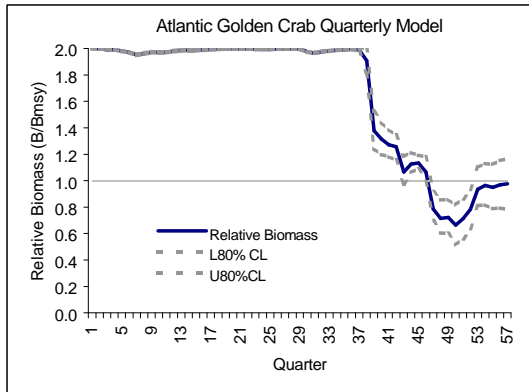
**Figure 6.** Median estimates of quarterly biomass (upper plate, solid line) and fishing mortality rate (lower plate, solid line) expressed relative to the levels estimated to produce MSY for the period 1986-1999, for the model assuming 1986 biomass was at carrying capacity fit to the 21 paired quarterly catch and effort observations. Dashed lines represent approximate 80% (upper) or 50% (lower) confidence ranges based on 501 bootstrap trials.

**Figure 7.** Median estimates of annual biomass (upper plate, solid line) and fishing mortality rate (lower plate, solid line) expressed relative to the levels estimated to produce MSY for the period 1986-1999, for the model assuming 1986 biomass was at carrying capacity fit to the 5 paired annual catch and effort observations. Dashed lines represent approximate 80% (upper) or 50% (lower) confidence ranges based on 501 bootstrap trials.

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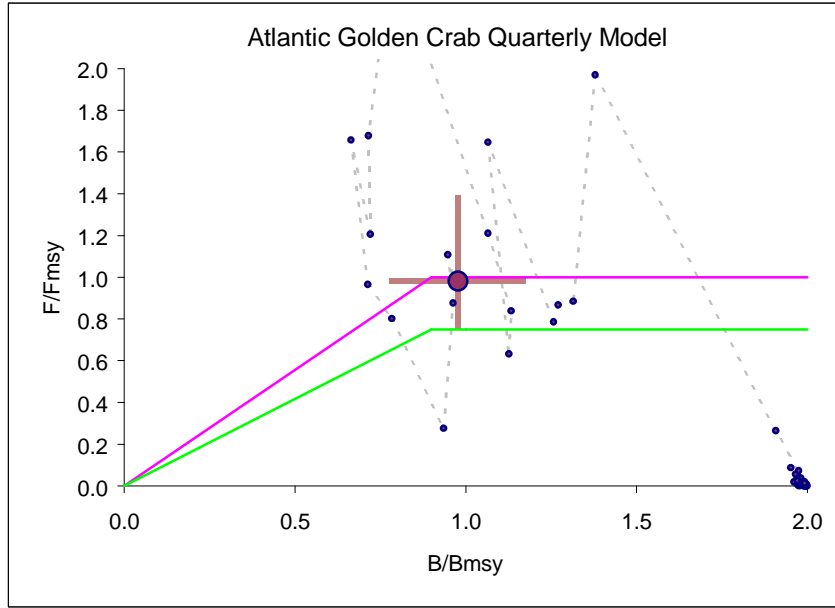
**Figure 8.** Phase plot showing trajectory (dashed line) of relative biomass and relative F (points) based on the quarterly data model fit. The median estimates of most recent ordered pair ($B_{March,2000}/B_{MSY}$, $F_{Qtr\,4,1999}/F_{MSY}$) of stock condition and fishing rate are represented by the large filled circle. Error bars around the circle represent bootstrap approximate 80% confidence ranges for relative B and relative F. Also indicated are example limit (upper jointed solid line, MFMT=$F_{MSY}$) and target (lower jointed solid line, Target F=0.75$F_{MSY}$) control rules, with MSST set at 0.9$B_{MSY}$ (corresponding to an assumed Golden Crab M=0.1).
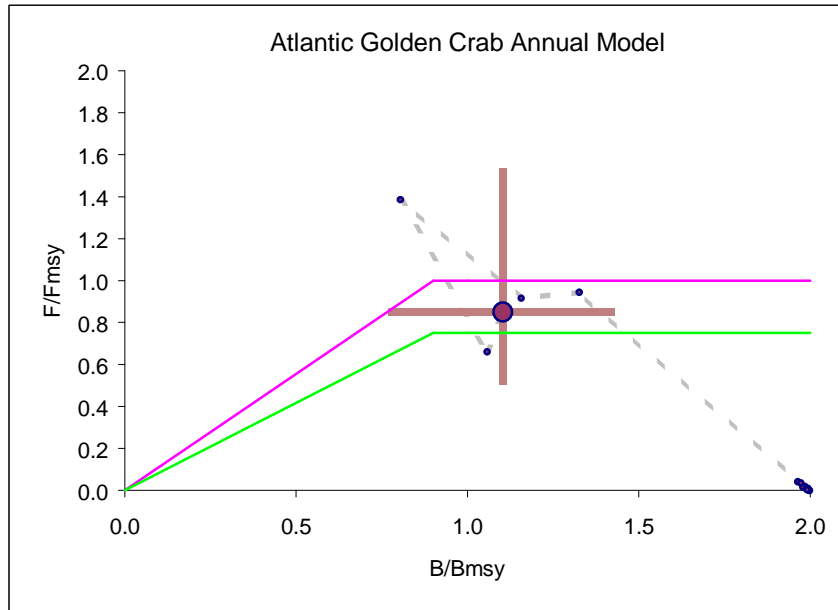


**Figure 9.** Phase plot showing trajectory (dashed line) of relative biomass and relative F (points) based on the annual data model fit. The median estimates of most recent ordered pair ($B_{2000}/B_{MSY}$, $F_{1999}/F_{MSY}$) indicating stock condition and fishing rate are represented by the large filled circle. Error bars around the circle represent bootstrap approximate 80% confidence ranges for relative B and relative F. Also indicated are example limit (upper jointed solid line, MFMT=$F_{MSY}$) and target (lower jointed solid line, Target F=0.75$F_{MSY}$) control rules, with MSST set at 0.9$B_{MSY}$ (corresponding to an assumed Golden Crab M=0.1).